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Pharmacological Activities of *Rosmarinus officinalis*: A Review

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ABSTRACT

Rosemary (*Rosmarinus officinalis*) is an aromatic evergreen plant indigenous to the Mediterranean region, valued for its, medicinal, and ornamental uses. Renowned for its robust flavor and fragrance, it is a staple in kitchens, used to enhance the taste of meats, vegetables, and breads. Beyond its culinary applications, rosemary is rich in antioxidants and contains anti-inflammatory and antimicrobial compounds, making it beneficial for digestion, memory enhancement, and overall health. It has been used in traditional medicine and aromatherapy to boost cognitive function and relieve stress for a long time. Culturally, rosemary symbolizes remembrance and fidelity, often featured in rituals and ceremonies. The herb is also easy to grow, thriving in sunny environments and well-drained soil, making it a popular choice for gardens. Rosemary's combination of versatility, health benefits, and cultural significance ensures its enduring role as a cherished plant across culinary, medicinal, and decorative domains.

Keywords: Rosemary, Rosmarinic acid, Carnosic acid, Anti-cancer.

INTRODUCTION

Rosemary (*Rosmarinus officinalis*) emerged in the Mediterranean region; it is now grown globally. It can be cultivated using seeds, cuttings, or root division[1]. This plant is an evergreen herb with aromatic leaves that can be harvested multiple times a year. Polyphenols are significant in rosemary, including carnosol, rosmarinic acid and carnosic acid. These compounds are known for their inflammation modulating, oxidative stress reducing, and antimicrobial properties. Rosmarinic acid is known particularly for its antioxidant properties and its effects on inflammatory mediators. Rosemary

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may help with conditions like bronchial asthma, spasmogenic disorders, peptic ulcers, inflammatory diseases, and many more.

They have variety of applications in food industries such as Rosemary serves as a flavoring agent, spice condiment, and preservative. The use of natural extracts as substitutes for synthetic food additives is becoming increasingly popular. *R. officinalis* extracts are valued for their antioxidant, antibacterial, and antifungal properties, which contribute to food preservation. They are also used for commercial and industrial purposes for its qualities[2]. Spain is a significant exporter and processor of rosemary, utilizing it for its antioxidant properties. The European Food Safety Authority (EFSA) approves the use of rosemary extracts in food and beverages. The beneficial effects of rosemary are achieved through mechanisms like inhibiting oxidative stress, reducing inflammatory mediators (e.g., TNF-α, IL-6), and regulating apoptosis and MAPK signaling pathways. The process of extracting its compounds and their impact on flavor, color, and odor is an important aspect of its application in food. This review emphasizes the interest in rosemary's therapeutic properties and its active components. Carnosol, rosmarinic acid and carnosic acid are emphasized for their roles in health benefits and food applications[3].

Pharmacological activity of rosemary

Anti-microbial

The aerial parts and essential oil of *Rosmarinus officinalis* (rosemary) have been investigated for their antibacterial, antifungal, antioxidant, and antiproliferative activities. Various studies highlight the potential of rosemary as a natural source of bioactive compounds.

Rosemary essential oil and its major constituents have demonstrated antibacterial activity, although the oil itself often showed lower efficacy compared to its pure major components. Among oral pathogens*, S. mitis* was the most susceptible, while *E. faecalis* was the most resistant. In one study, *Rosmarinus officinalis* oil inhibited ethidium bromide efflux, indicating its potential to target bacterial efflux pumps, though not necessarily NorA pumps.

The essential oil, particularly rich in compounds like 1,8-cineole, camphor, and αpinene, exhibited notable antioxidant properties, reducing DPPH radicals in a dose-dependent manner. It also showed antiproliferative effects against cancer cell lines such as MCF-7 and LNCaP.

While the antimicrobial activity varied, some strains, including those of *Fusarium graminearum*, experienced fungal growth induction. This variability underlines the complexity of rosemary's bioactive properties. Rosemary's essential oil and pure compounds remain promising for applications in antimicrobial, antioxidant, and antiproliferative therapies[4].

Anti-depressants

Research indicates that *Rosmarinus officinalis* (rosemary) shows potential as an antidepressant based on studies using the Tail Suspension Test (TST) and Forced swimming Test (FST) in mice. These tests demonstrate that rosemary consistently reduces immobility time, suggesting antidepressant-like effects. Furthermore, rosemary alleviated symptoms such as reduced exploratory behavior and anhedonia in bulbectomized mice, strengthening its antidepressant potential[5].

The antidepressant activity of the concerned is thought to stem from its interaction with the monoaminergic system, enhancing dopaminergic, noradrenergic, serotonergic and cholinergic functions in the brain. This interaction may explain its ability to increase neurotransmitter concentrations, further supporting its therapeutic effects[6].

Key compounds responsible for these effects include carnosol, betulinic acid, polyphenols and ursolic acid found in rosemary extracts and essential oils. These bioactive compounds likely contribute to its modulation of brain function.

Overall, rosemary exhibits significant antidepressant-like properties, with evidence pointing to its capacity to improve mood and behavior through neurotransmitter enhancement and interaction with brain systems critical for emotional regulation[7].

Anti-obesity

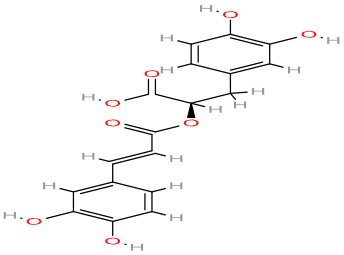
Studies have investigated the effects of rosemary (*Rosmarinus officinalis* L.) leaf extract (RE) on preventing weight gain and metabolic disorders

Table 1: Composition of rosemary

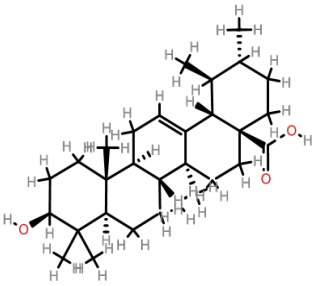
S. No.	Composition	Molecular formula	Parts from which it extracted	Pharmacological activity
1	Rosmarinic Acid	$C_{18}H_{16}O_8$	Leaves	Antioxidant,Anti-inflammatory, Antimicrobial, Neuroprotective, Anticancer Cardioprotective,Antidiabetic[31].
2	Ursolic Acid	$C_{30}H_{48}O_3$	Leaves	Anti-inflammatory, Antioxidant, Anticancer, Antimicrobial, Metabollic Benefits, Neuroprotective effects, Cardio protective effects
3	Carnosic Acid	$C_{20}H_{28}O_4$	Leaves	Antioxidant, Anti-inflammatory, Neuroprotective, Anticancer, Antimicrobial, Cardiovascular benefits[28].
4	Caffeic Acid	$C_9H_8O_4$	Leaves	Anti-inflammatory, Antioxidant, Anticancer, Antimicrobial,Metabolic benefits, Neuroprotective,Cardioprotective effects
5	Betulunic Acid	$C_{30}H_{48}O_3$	Leaves	Antitumor, Antiviral, Anti-inflammatory, Antioxidant, Neuroprotective effects, Antimicrobial
6	Pantothenic Acid	$C_9H_{17}NO_5$	Young leaves and shoots	Energy metabolism, Wound healing, Stress response, Neuroprotective effects, Cholesterol regulation, Antioxidant
7	Rosmanol	$C_{20}H_{26}O_5$	Leaves	Anti- inflammatory, Antioxidant, Antimicrobial, NeuroprotectiveEffects, Antispasmodic
8	Carnosol	$C_{20}H_{26}O_4$	Leaf trichomes	Anti-inflammatory, Antioxidant, Antimicrobial, Anticancer, Neuroprotective effects, metabolic regulation
9	Camphene	$C_{10}H_{16}$	Leaves	Anti- inflammatory, Antioxidant, Antimicrobial, Analgesic effects, Respiratory benefits, Potential anti-cancer activity
10	Limonene	$C_{10}H_{16}$	Leaves	Anti-inflammatory, Antioxidant, Antimicrobial, Anticancer, Mood enhancement, Digestive health, Metabolic benefits
11	Camphor	$C_{10}H_{16}O$	Leaves	Anti-inflammatory, Analgesic properties, Respiratory benefits, Stimulant effects, Anxiolytic properties, Neuroprotective effects[56]
12	Borneol	$C_{10}H_{18}O$	Aerial parts	Anti-inflammatory, Analgesic effects, Antimicrobial, Neuroprotective effects, Cognitive enhancement, Sedative effects, Antioxidant
13.	Cineole	$C_{10}H_{18}O$	Leaves	Anti-inflammatory, Antioxidant, Antimicrobial, Mood enhancement, Cognitive enhancement, Analgesic effects, Expectorant properties
14	Linalool	$C_{10}H_{18}O$	Flowers and leaves	Anti-inflammatory, Analgesic effects, Anxiolytic effects, Antimicrobial, Neuroprotective effects, Antioxidant, Sedative effects

15	Verbinol	$C_{20}H_{36}O$	Flowers and leaves	Anti-inflammatory, Antioxidant, Antimicrobial, Anticancer, Sedative effects
16	Niacin	$C_6H_5NO_2$	Flowering tops and leaves	Lipid regulation, Vasodilatory effects, Metabolic support, Neuroprotective effects, Anti-inflammatory skin health
17	Thiamine	$C_{12}H_{17}N_4OS$	Leaves	Energy metabolism, Nervous system support, Cardiovascular health, Antioxidant, Neuroprotective effects, Role in digestion
18	Folate	$C_{19}H_{19}N_7O_6$	Leaves	DNA synthesis and Repair, Red blood cell formation, Neural tube development, Amino acid metabolism, Antioxidant, Cognitive function, Potential cancer prevention
19	Riboflavin	$C_{17}H_{20}N_4O_6$	Leaves	Energy metabolism, Antioxidant,Red blood cell production, Skin and Eye health, Neuro protective effects, Metabolism of other vitamins, Potential migraine

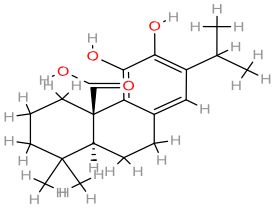
Structures of active constituents of rosemary



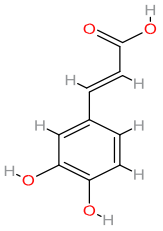
1. Rosmarinic Acid



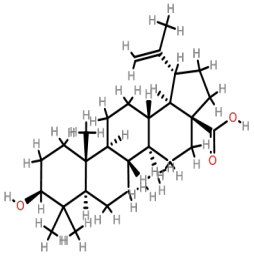
2.Ursolic Acid



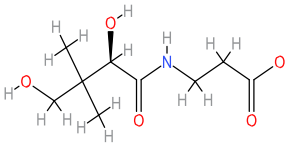
3. Carnosic Acid



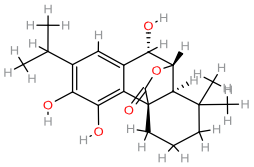
4.Caffeic Acid



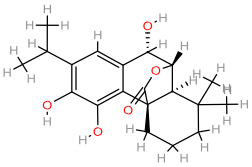
5.Betulunic Acid



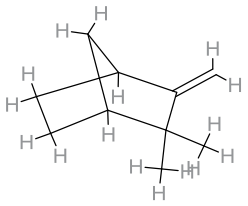
6.Pantothenic Acid



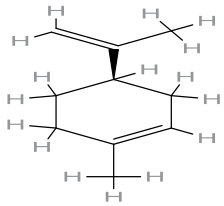
7. Rosmanol



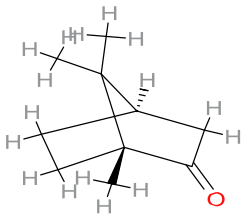
8. Carnosol



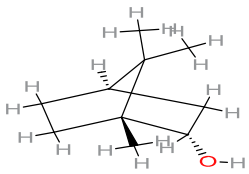
9.Camphene



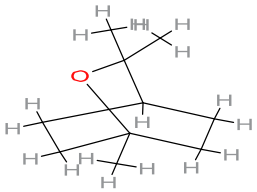
10. Limonene



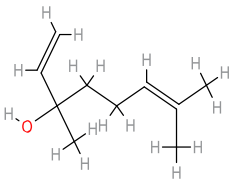
11.Camphor



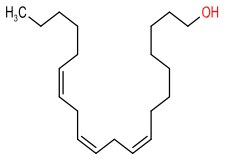
12.Borneol



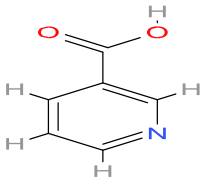
13.Cineole



14.Linalool



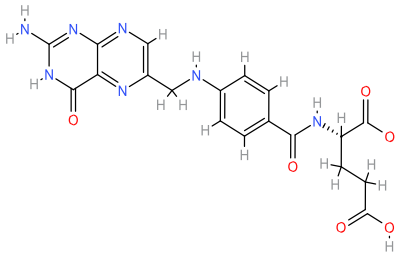
15.Verbinol



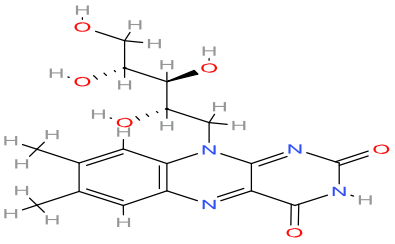
16. Niacin



17. Thiamine



18.Folate



19. Riboflavin

in mice fed a high-fat diet. While RE treatment did not affect glucose tolerance or fasting glycemia, it significantly reduced hepatic triglyceride levels by 39% in treated mice. However, a lower dose of RE (20 mg/kg BW) showed no impact on any measured parameters. The findings suggest that consuming 200 mg/kg BW of RE can mitigate high-fat diet-induced weight gain and protect against obesity-related liver steatosis[8].

Additional studies reported that rosemary extract lowered plasma alanine aminotransferase levels at the end of the experimental period. At a dose of 600 mg/kg, it reduced plasma glucose and triglyceride levels by week 4, and improved the HDL/LDL cholesterol ratio by week 12, indicating enhanced lipid transport and energy metabolism[9].

Furthermore, research on the metabolic effects of rosemary extract revealed that it significantly increased glucose consumption in HepG2 cells. This effect was diminished by the PPARαspecific antagonist GW9662, suggesting that rosemary extract may enhance liver glycolysis and fatty acid oxidation through activation of AMPK and PPAR pathways[10].

Neuroprotective

Rosmarinus officinalis (rosemary) has shown promising neuroprotective properties, particularly against neurodegenerative diseases like Alzheimer's disease and dementia[11]. Its effectiveness is primarily linked to its inhibitory effects on the enzymes acetyl cholinesterase (AChE) and butyrylcholinesterase (BChE), both of which are involved in the breakdown of acetylcholine—a neurotransmitter crucial for memory and cognitive function. By reducing enzyme activity, rosemary helps to maintain higher acetylcholine levels in the brain, potentially improving memory and cognitive health[12].

The active compounds responsible for these effects include rosmarinic acid and terpenes found in rosemary's essential oil[13]. Additionally, these compounds are believed to increase total brain choline levels, which could mitigate not only Alzheimer's symptoms but also anxiety, depression, and memory loss[14].

Supporting studies have identified polyphenols in rosemary extract as contributors to its neuroprotective abilities[15]. These findings underscore rosemary's potential as a natural therapeutic agent for cognitive health[16].

Anti diabetic

Diabetes mellitus is a rapidly increasing global health challenge, projected to affect 300 million people by 2025, with annual treatment costs potentially reaching $1 trillion. High oxidative stress plays a significant role in diabetes development, particularly damaging pancreatic α cells, which reduces insulin secretion and raises blood glucose levels[17].

Natural antioxidants, particularly those from plants, are gaining attention as potential treatments for diabetes. Among these, *Rosmarinus officinalis* (rosemary) has emerged as a promising antidiabetic agent due to its strong antioxidant properties[18]. Studies demonstrate that rosemary extract can lower blood glucose levels in normoglycemic, hyperglycemic, and diabetic animal models. Its mechanisms include inhibiting lipid peroxidation, enhancing antioxidant enzyme activity, =and stimulating insulin secretion. Additionally, rosemary has been shown to improve wound healing, addressing one of the serious complications of diabetes[19]. These effects are attributed to the improved antioxidant status in the body following rosemary administration, highlighting its potential as a natural and effective therapeutic agent for diabetes management[20].

Antioxidant

The antioxidant activity of *Rosmarinus officinalis* (rosemary) is extensively documented, primarily due to its high levels of phenolic diterpenes, particularly carnosol, carnosic acid, and rosmarinic acid[21]]. These compounds, found in the plant's essential oils and extracts, are key to its antioxidant properties[22]. Rosemary's antioxidant effects occur through multiple mechanisms:

1. Free Radical Scavenging: Rosemary essential oil and extracts help destroy and prevent free radicals[23].
2. Lipid Peroxidation Prevention: It protects against oxidative stress-induced lipid damage[24].
3. Antioxidant Enzyme Activation: Rosemary enhances the activity of endogenous antioxidant enzymes, improving the body's natural defense systems[25].

These actions reduce oxidative stress, which is linked to the development of diseases like diabetes and cancer[26]. By counteracting oxidative



Fig. 1: Rosemary Plant[57]

damage, rosemary helps prevent such conditions that are caused by free radical accumulation[27,28,29].

Anti-cancer

Rosemary (*Rosmarinus officinalis*) demonstrates promising anticancer potential, primarily attributed to its bioactive diterpenes such as carnosol, carnosic acid, and rosmanol. These compounds modulate deregulated signaling pathways, including those related to cell cycle regulation and apoptosis, across various solid and blood cancers. Their molecular mechanisms, evaluated through preclinical studies, highlight their ability to target pathways involved in tumor growth and survival. For instance, carnosic acid and carnosol have demonstrated the ability to inhibit prostate cancer by modulating cell cycle and apoptosis-related pathways, suggesting potential for chemoprevention[30].

Rosemary extracts and their isolated components are generally well-tolerated in animal studies, as evidenced by their approval as antioxidant food preservatives by regulatory bodies such as the EU and FDA. However, the genotoxic and mutagenic effects of rosemary essential oil at higher doses in rodent models indicate potential safety concerns, warranting caution in its use.

In liver cancer studies, rosemary essential oils influenced the regulation of apoptosis-related genes (bcl-2 and bax) in the HepG2 cell line, promoting apoptosis[31]. Additionally, research on Salvia fruticosa and R. officinalis revealed shared metabolic pathways involving ferruginol synthesis, an intermediate in diterpene production, expanding understanding of the biosynthesis of these bioactive compounds in the Lamiaceae family[32].

Overall, rosemary's anticancer effects are attributed to its ability to modulate critical signaling pathways and gene expression. While the phytochemicals hold promise for cancer therapy and chemoprevention, further studies are needed to address safety concerns, explore synergistic effects of whole extracts, and validate findings for potential therapeutic applications[33].

Anti-bacterial

The antibacterial activity of *Rosmarinus officinalis* (rosemary) and Petroselinum crispum (parsley) extracts was assessed against bacteria causing urinary tract infections[34]. While fractions and pure rosmarinic acid showed limited effects against Gram-negative bacteria, fractions 2, 3, and 4 demonstrated promising bactericidal activity against Gram-positive bacteria, including Staphylococcus epidermidis and *Enterococcus faecalis*[35]. This suggests the potential of R. officinalis as a natural alternative for treating urinary infections. Furthermore, the antibacterial and antioxidant activities of the extracts were influenced by the concentrations of key compounds like carnosic acid and carnosol[36]] Although both diterpenes contributed equally to antioxidant effects, the antibacterial activity improved when carnosol predominated. Additionally, R. officinalis essential oil, rich in compounds like α-pinene, β-pinene, and 1,8-cineole showcased greater antibacterial and anticancer properties compared to its individual components. The effectiveness of these plant-derived substances was dose-dependent, with varying levels of cytotoxicity observed in different cancer cell lines[37]. These findings highlight the therapeutic potential of R. officinalis and its bioactive compounds, suggesting their role in developing effective treatments for infections and as possible anticancer agents, while underscoring the importance of concentration and compound synergy in determining biological activity[38].

Antiviral

Rosmarinic acid, a compound found in rosemary, has demonstrated significant antiviral properties against several viruses, including HIV, enterovirus 71 (EV71), influenza and hepatitis B virus (HBV). Studies have shown that rosmarinic acid can interact with NO2- to form nitro derivatives, which enhance its antiviral activity, particularly by inhibiting HIV-1 integrase and viral replication in MT-4 lymphocyte cells. In the case of HBV, rosmarinic acid targets the viral polymerase through its unique structure, interfering with the key process of HBV replication. It has also been shown to protect cells from enterovirus 71-induced damage, with the greatest efficacy at the early stages of infection. Furthermore, rosmarinic acid, through its inhibitory effects on influenza virus replication, also helps reduce virus-induced lung damage. While nucleoside analogues (NAs) are currently used to treat hepatitis B, rosmarinic acid offers potential as an alternative or adjunctive therapy in combating viral infections,

highlighting its broad-spectrum antiviral effects. Its ability to inhibit viral replication at different stages makes it a potential candidate for further research and development in antiviral drug therapy[39].

Antitumor

Carnosol and rosmarinic acid, two key compounds found in rosemary, have demonstrated significant anticancer properties across various cancer types, including breast, liver, colon, and prostate cancers. Studies highlight that carnosol effectively suppresses the growth of estrogen receptor-positive breast cancer cells, such as T47D and MCF-7, by increasing the ratio of estrogen receptor subtype and blocking cell proliferation in the S phase[40]. Additionally, it prevents migration and induces apoptosis in these cells. Similarly, rosmarinic acid has shown promise in reducing the proliferation and migration of breast cancer cells, including MDA-MB-231, by promoting apoptosis and altering cancer cell signaling pathways. Beyond breast cancer, rosmarinic acid exhibits inhibitory effects on liver cancer cells, including Huh7, by regulating apoptosis-related proteins like Bcl-2 and Bax. It also suppresses tumor growth in animal models[41]. Moreover, both compounds exhibit anti-cancer effects in colon, prostate, and kidney cancers[42]. Rosmarinic acid inhibits tumor growth and the formation of abnormal crypt foci in colon cancer, while carnosic acid induces apoptosis in renal cancer cells[43]. These findings suggest that rosemary-derived compounds hold potential as natural therapeutic agents for various cancers by regulating critical cancer-related signaling pathways and inducing apoptosis[44].

Ulcerative Colitis

This study investigates the potential therapeutic effects of rosemary leaves essential oil (REO) and hydroalcoholic extract (RHE) on experimental colitis induced by trinitrobenzene sulfonic acid (TNBS) in rats. Colitis was induced by intracolonic instillation of TNBS, and various doses of RHE (100, 200, 400 mg/kg) and REO (100, 200, 400 µL/kg) were administered both orally and intraperitoneally, 6 hours after induction for 5 days. The study measured colon weight/length ratio, tissue damage scores, and histopathological indices to assess the extent of colonic injury and inflammation. Results showed that both REO and RHE, at all tested doses, significantly reduced colon tissue lesions and colitis severity. Higher doses are particularly effective in diminishing histopathological damage, regardless of the administration route. These findings suggest that rosemary's bioactive compounds may have potent anti-inflammatory properties, potentially offering an alternative or adjunct to conventional treatments for inflammatory bowel disease (IBD), such as prednisolone, Asacol, and hydrocortisone acetate. The study supports the traditional use of rosemary in treating gut inflammation and highlights its potential as a natural remedy for IBD[45].

Hepatoprotective

Several studies have assessed the hepatoprotective and antidiabetic effects of Rosmarinus officinalis (rosemary) extracts, highlighting its potential therapeutic applications[46]. The water extract of rosemary (200 mg/kg) showed significant protective effects in streptozotocin (STZ)-induced diabetic rats, demonstrating both hepatoprotective and antidiabetic properties. Similarly, lyophilized ethanol and aqueous extracts of rosemary, especially from young sprouts, exhibited notable choleretic and hepatoprotective activities, with ethanol extracts being more potent in choleresis, and aqueous extracts showing protective effects against carbon tetrachloride (CCl_4)-induced liver damage[47]. Phytochemical analysis revealed that the methanol extract of rosemary leaves (MEROL) has antioxidant properties, reducing hepatotoxicity induced by CCl_4 through lowered AST levels and improved lipid profiles[48]. Additionally, rosemary's effects on liver injury were further confirmed in studies showing partial protection against CCl_4-induced liver inflammation and necrosis. The presence of phenolic compounds, particularly in rosemary essential oil and ethanol extracts, contributes to its antioxidant and hepatoprotective effects[49]. Moreover, rosemary extracts may influence the expression of glutamate receptor subunits, improve liver function and provide neuroprotective benefits in cirrhotic rats[50]. These findings underscore the potential of *Rosmarinus officinalis* as a natural remedy for liver protection and diabetes management[51].

Antidermatophytic

Recent studies have highlighted the diverse pharmacological benefits of Rosmarinus officinalis (rosemary) extract, demonstrating its potential in various therapeutic applications[52]. In one study, rosemary extract significantly improved skin flap

survival in rats, suggesting its potential for enhancing tissue repair and healing. Additionally, a combination of rosemary and grapefruit extracts was found to decrease susceptibility to UV radiation, reducing skin redness, lipoperoxides, and improving skin elasticity and wrinkle formation, which may be ascribed to the inhibition of UV-induced oxidative stress and inflammation[53]. Rosemary's antifungal properties were also explored, with hydroalcoholic extracts demonstrating efficacy against dermatophytes like Trichophyton and Microsporum species, indicating its potential for developing antifungal treatments[54]. Furthermore, rosemary essential oil was shown to enhance the transdermal absorption of diclofenac, suggesting its utility in improving drug delivery through the skin. Lastly, rosemary extracts, particularly carnosol (CS) and carnosic acid (CA), exhibited significant anti-inflammatory effects by inhibiting nitric oxide production and modulating inflammation-related genes, reinforcing the therapeutic potential of rosemary in managing inflammation[55] Together, these studies underscore rosemary's broad-spectrum of bioactive properties, positioning it as a valuable candidate in dermatological, antifungal, and anti-inflammatory treatments[56]

CONCLUSION

Rosemary (*Rosmarinus officinalis*) is a versatile herb known for its medicinal, and ornamental value. Indigenous to the Mediterranean region, it is an evergreen shrub with needle-like leaves and a strong, aromatic fragrance. In the culinary world, rosemary is prized for its robust flavor, often employed to season meats, vegetables, and breads. Its distinctive aroma enhances dishes, making it a staple in many kitchens. Beyond that, rosemary has significant medicinal properties. It is rich in antioxidants and contains anti-inflammatory and antimicrobial compounds, which support digestion, boost memory and cognitive function, and promote overall health. Traditionally, it has been applied to improve concentration and relieve stress. Rosemary essential oil is also popular in aromatherapy for its invigorating effects. Culturally, the herb symbolizes remembrance, love, and fidelity, often featured in weddings and funerals. It is easy to grow, thriving in well-drained soil and sunny locations, making it a popular choice for home gardens and decorative landscaping. In conclusion, rosemary is more than just a flavourful herb—it is a valuable plant with a rich history of utilization and benefits. Its enduring popularity stems from its unique combination of utility, beauty, and cultural significance.

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Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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